A LETTER *to the* AUTHOR *of the preceding* PAPER, *with* REMARKS *and* HINTS *for the* FURTHER IMPROVEMENT *of* BAROMETERS.

By H. HAMILTON, *D. D. Dean of Armagh, F.R.S.* *and M. R. I. A.*

DEAR SIR,

I HAVE read the account you fent me of your portable barometer, and as you defire my opinion of that inftrument I fhall give it very freely. The form and ftructure of your barometer is as fimple and convenient as can be. The ivory box is fo clofed by a cork, through which the tube paffes, that the mercury cannot get out, however the inftrument is placed or agitated. But it feems to me that the clofenefs of the cork, which is fufficient to prevent the mercury from efcaping, will alfo prevent the free communication that ought to be between the

Read Dec. 1, 1792.

the outward air and that in the box. And even ſuppoſing the pores of the cork were at firſt ſufficiently permeable by air, yet they may be in time obſtructed by duſt, the cork may imbibe moiſture which will contract or ſtop its pores; and, as there is no hole to drop in a floating gage, you cannot at any time meaſure accurately the height of the mercury, or be ſure it is the ſame that it would be were the barometer open. I would therefore recommend that, inſtead of a cork, the top of your box ſhould be of ivory, with a hole to drop in a floating gage, which is the caſe in all other portable barometers. This hole you may occaſionally ſtop with a peg or ſcrew, and then the inſtrument will be ſafely portable: or perhaps it might be better to have a cover to ſcrew over the top of the box, and a hole in it to correſpond with the one in the box. When theſe two holes are together the box is open; and it is ſhut when the holes are removed from each other by turning the cover and ſcrewing it tight to the top of the box, and if there be a plate of ſoft leather between them, it will be ſufficient to keep in the mercury when the inſtrument is agitated by carriage. That I might let you know whether this ſcheme would ſucceed I have had a barometer made in this form, and find it anſwers all the purpoſes of an open and of a portable one. The tube is not incloſed, like your's, in a mahogany ſtaff, but fitted in a frame of the uſual form. There have been various other methods propoſed for making barometers portable, but all thoſe I have met with are of a conſtruction more complex than is neceſſary. I have ſeen one made for the late Doctor Uſsher by Nairne and Blount,

Blount, in the manner ſaid to be moſt approved of by the Royal Society. In this inſtrument the box has a leathern bag or moveable bottom, which being ſcrewed up raiſes the mercury till it fills both the box and the tube; then the hole made for admitting the floating gage is ſtopped and the inſtrument becomes portable. Theſe contrivances for keeping the box and tube full of mercury ſeem to have been thought neceſſary from a miſtaken notion, that if air was included in the box its elaſticity would (when the inſtrument was ſuddenly inclined) force the mercury againſt the top of the tube ſo violently as to break it, which has often happened in an open barometer; but this is not the caſe, for I have ſeen your cloſe barometer ſuddenly inclined, and the included air did not make the mercury ſtrike the top of the tube with any violence. I am therefore of opinion that your barometer, if the box was made to be occaſionally opened or ſhut, would have the moſt ſimple and convenient form, and would be leſs liable than any other to be put out of order, or to require readjuſtment or repairs, as I am told Doctor Uſsher's barometer, now in the obſervatory, frequently does. The true altitude of the mercury, in a barometer, is the diſtance between the ſurface of the mercury in the tube and in the box; when therefore the ſurface in the box is ſo large that it will not riſe or fall ſenſibly, as the mercury falls or riſes in the tube, the common ſcale, if rightly adjuſted at firſt to the height of the mercury, will continue to point out its true height afterwards. This is the caſe in fixed barometers, which have uſually very large veſſels to hold the

ſtagnant

ftagnant mercury. But in thefe portable barometers with narrow boxes, though the common fcale be adjufted at firft to the true height of the mercury, it will not fhew its true height afterwards when the mercury has rifen above, or fallen below, that point or divifion of the fcale where it ftood at firft. For as the box is narrow, the height of the mercury will vary in the box whenever it varies in the tube, and it is the fum of thefe two variations that gives the true variation which has taken place in the height of the elevated mercury. Now the fcale annexed to the tube only fhews one of thefe variations; and therefore when the mercury ftands above or below the divifion of the fcale to which its real height was at firft adjufted, we cannot tell, by merely infpecting the fcale, how many aliquot parts of an inch the height of the mercury has varied, or how much it differs from the height it had when it ftood at that divifion to which it was adjufted at firft. Confequently when the mercury departs from that divifion the fcale will not fhew its true altitude in inches and aliquot parts of an inch.

To correct this error of the fcale, by which the variations in the height of the mercury alway appear lefs than they really are, you propofe that tables fhould be formed which may fhew what additions ought to be made to each particular variation. This however might be done in an eafier way than by tables previoufly calculated: For when you have found the proportion between the furface of the mercury in the box and that in the tube, fay as the furface in the box is to the fum of the

the two ſurfaces, ſo is the apparent variation in the tube to the ſum of the variations in the tube and box, which gives the true variation. But as applying this correction to all the ſeveral variations in a ſeries of obſervations would be troubleſome and tedious, I think it would be much better to form, at once a ſcale which ſhould need no correction; and this may be done by reducing the common ſcale of inches, that is, by making a ſcale whoſe diviſions ſhall be leſs than the correſpondent diviſions of the common ſcale, in the ſame proportion that the apparent variation in the tube of your barometer is leſs than the true one; and this proportion is always conſtant in the ſame barometer; for it is that proportion which the ſurface of the mercury in the box bears to the ſum of its ſurfaces in box and tube. If this contracted ſcale be annexed to the tube of the portable barometer, it is evident that, when the mercury has varied through any of the contracted diviſions of this ſcale, it will have varied, at the ſame time, through the correſponding diviſions of the common ſcale annexed to the tube of a fixed barometer. Therefore this contracted ſcale will always point out the variations and altitudes of the mercury truly, or ſuch as the common *inch-ſcale* ſhews them to be at the time in a fixed barometer whoſe box is of the largeſt dimenſions. To illuſtrate this by an example: ſuppoſe that in a portable barometer the ſurface of the mercury in the box is to that in the tube as 49 to 1, then it will be to the ſum of the ſurfaces as 49 to 50; and when the mercury in the tube falls through $\frac{49}{50}$ of an inch, it will riſe in the box $\frac{1}{50}$; ſo that its true fall, at that time, will be one inch. If then

to this barometer a ſcale be adapted in which a line $\frac{49}{50}$ of an inch be made to repreſent one inch, when the mercury falls through the length of this line its altitude will be really leſſened by one inch. And thus the diviſions of this ſcale will repreſent the true variations and altitudes of the mercury in inches, as correctly as the common ſcale can do in any large fixed barometer. This corrected ſcale is to be divided into aliquot parts ſimilar to thoſe in the common *ſcale of inches*; and to its diviſions are to be annexed the ſame figures or numbers that are annexed to the correſponding diviſions of the common ſcale.

THE eaſieſt, and, I believe, the moſt accurate method of forming a correct ſcale for a portable barometer, is this: put it up by a fixed barometer, whoſe veſſel, for the ſtagnant mercury, is ſo large that you may be ſure the ſurface of the mercury in it will not riſe or fall perceptibly on its riſing or falling in the tube; ſo that the common ſcale, annexed to this large barometer, will always point out the true variations and altitudes of the mercury in the tube. Mark, at the ſame time, the points at which the mercury ſtands in the tube of each barometer. When you find that the mercury in the fixed barometer has varied through any given ſpace, ſuppoſe one inch, then take accurately the length of the ſpace through which it has varied at that time in the portable barometer; this will be the length of a line which is to repreſent one inch in the correct ſcale for that portable barometer. That this obſervation may be accurate it ſhould be repeated often. In this

way

way of making a ſcale we avoid the trouble of meaſuring exactly the diameters of the box and of the tube, and of its orifice or bore, and of finding out from thence what is to be the length of our corrected ſcale. Inſtead of this we have only the length of one ſpace or line to meaſure, and this gives the length of our ſcale without any calculation. It is ſo convenient to have a correct ſcale, ſuch as I have mentioned, for a barometer, and the method of making one is ſo ſimple and obvious, that we may wonder it has not long ſince been known and practiſed.

We ſee that, according to this ſcheme, every portable barometer muſt have a ſcale made purpoſely for itſelf, and a vernier adapted to that ſcale; ſo that to get ſuch a ſcale made we muſt beſpeak it, and tell the proportion we would have its aliquot parts bear to thoſe of the common *inch-ſcale*. If it be thought that this is any inconvenience, and that it would be deſirable that all portable barometers ſhould uſe one common ſcale, which might be had ready made with a vernier adapted; this is a thing that may be eaſily effected, if it was generally agreed what the length of that common ſcale ſhould be. I would therefore propoſe, for inſtance, that the length of the ſcale ſhould be $\frac{1}{50}$ leſs than the ſcale of three inches now in uſe, which would be no great diminution. And in this caſe an artificer would have a very eaſy rule by which he might ſo conſtruct his barometers, that the ſcale now propoſed ſhould anſwer for them all. The rule is this, meaſure the external diameter of the tube you intend to uſe, and the diameter of its orifice or bore;

make a right-angled triangle, one ſide of which ſhall be equal to the diameter of the tube, and the other ſide ſeven times the diameter of the bore, the hypotenuſe will be the proper diameter for the box, ſo that the ſcale now propoſed ſhall be a correct ſcale for that barometer. The reaſon of this is plain: For in the barometer, thus conſtructed, the ſquare of the diameter of the box is equal to the ſquare of the diameter of the tube, and alſo to 49 times the ſquare of the diameter of the bore; therefore (ſince circles are as the ſquares of their diameters) the area of the box is equal to the area occupied by the lower end of the glaſs tube, and to 49 times the area of the bore of the tube. And therefore the annular area in the box, occupied by the ſurface of the mercury, is 49 times the ſurface of the mercury in the tube, conſequently it is to the ſum of theſe two ſurfaces as 49 to 50, and therefore it follows, from what has been ſaid, that the propoſed ſcale, whoſe length is to that of the common ſcale as 49 to 50, will be the proper correct ſcale for this barometer.

The foregoing rule, when expreſſed in general terms, will direct us how to conſtruct a portable barometer, whoſe contracted or correct ſcale ſhall bear any given proportion we pleaſe to the common ſcale of inches. Take two numbers, differing by a unit, the leſſer of which ſhall be to the greater in the proportion we intend the contracted ſcale ſhall have to the common one: then as a unit is to the leſſer of theſe numbers, ſo let the diameter of the bore of the tube be to another line; between this line and the diameter of the bore find a mean proportional,

proportional, and make it one ſide of a right-angled triangle, and let the other ſide be equal to the diameter of the tube. The hypotenuſe will be the diameter that the box of the barometer ought to have, in order that the propoſed ſcale may be the proper ſcale for it.

PORTABLE barometers have the advantage of being filled with leſs trouble than the common ones; for when the tube is filled, we have nothing more to do than to pour into the box as much mercury as we are ſure will cover the orifice of the tube, in whatever poſitions the inſtrument may be placed, and then ſcrew the cover on the bottom of the box with a collar of leather to prevent the mercury from getting at the threads of the ſcrew. The upper part of the box, which is ſolid, ought not to be leſs than $\frac{3}{4}$ of an inch in length, that it may take a ſufficient hold of the tube cemented into it. The end of the tube ſhould go into the cavity of the box ſo far as the middle of its length, and we ought to pour into the box as much mercury as will leave only $\frac{1}{4}$ of an inch in length to be occupied by the air when the barometer is erect; this ſpace will be ſufficient to allow the mercury in the tube to fall through ten or twelve inches, which will be full enough for meaſuring the heights of any places to which we uſually have acceſs, and we may be then ſure we have put in as much mercury as will cover the orifice of the tube in any poſition of the inſtrument. One reaſon, I believe, why it was thought neceſſary that air ſhould be excluded from the box of a barometer, while it was carried from one place to another, was, that the mercury would

be

be more apt to imbibe the air into its pores when they were agitated together by the carriage. If, on this account, it be thought beſt to prevent ſuch agitation, it may be done more eaſily than by any of the contrivances I have met with; for, when the gage-hole is ſtopped, invert the inſtrument, unſcrew the bottom of the box, and put in a piece of cork that may fill the ſpace which was occupied by the air, and the cover being ſcrewed on again will keep all tight. The cork having a thread put through it will be eaſily removed, and it ought to go into the box ſo eaſily as to let the air paſs out by its ſides. I have not met with any experiments made to ſhew what quantity of air mercury will abſorb after being well purged of air. An experiment for this purpoſe may be conveniently and accurately made in the following manner: As ſoon as a portable barometer is filled with mercury, well purged of air, let it be hung up along with a thermometer in a cool place, where the temperature of the air is not like to vary; and, when the mercury has attained the temperature of the place, ſhut the box of the barometer and mark the height at which the mercury then ſtands. On this occaſion not more than $\frac{1}{10}$ of an inch in length ſhould be left for the air in the box. When the barometer has remained in this ſituation for ſome time (during which the mercury in it ſhould be now and then agitated), if it has imbibed any proportion of the included air, ſuppoſe $\frac{1}{10}$, the air will then have loſt $\frac{1}{10}$ of its elaſticity, and conſequently the column of mercury ſuſtained will loſe $\frac{1}{10}$ of its height, or will have deſcended in the tube about three inches. Thus the deſcent of the mercury will ſhew accurately the proportion of the air that has been abſorbed.

As

As you have turned my attention to this ſubject, I now ſend you ſuch remarks as have occurred to me; ſome of which may poſſibly be uſeful to thoſe who are employed in barometrical obſervations.

I am, dear Sir,
Your's, &c.
H. HAMILTON.

Dublin, February 6th, 1792.
To the Rev. Doctor J. A. Hamilton.

POSTSCRIPT.

I FIND the mercury in my portable barometer (now a conſiderable time in uſe) varies as freely, when the cover is ſcrewed cloſe to the top of the box, as it could do in any open barometer; for I never could perceive the leaſt alteration in the height of the mercury upon opening the hole in the box after it had been a long time cloſed, ſo that the air muſt have free acceſs to the box though it is cloſe enough to retain the mercury perfectly. The ſame thing may happen in other cloſe barometers, and when it does happen it is an advantage, as it ſaves the trouble of turning the cover and bringing together the holes in it and the box, whenever we would know the height of the mercury. I therefore thought this circumſtance worth mentioning. This kind of barometer will ſerve juſt as well at ſea as at land, and will ſupply what has been much wanted; as none of the contrivances for a marine barometer have been found to anſwer the purpoſe ſufficiently.